Property and Effect of Saharan Dust over Sal Island, Cape Verde, Captured by SMART-COMMIT

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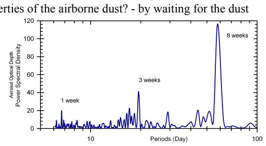
Background

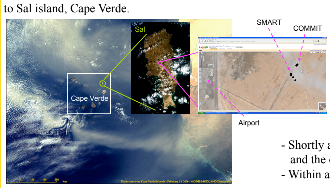
SMART and COMMIT are two ground-based mobile laboratories built in Goddard Space Flight Center for remote sensing of atmospheric radiation and in-situ measurement of aerosol properties. Sitting at a site watching the sky day and night – the remote sensing of Saharan Air Layer by SMART is straight forward, but how can COMMIT capture the physical and optical properties of the airborne dust? - by waiting for the dust layer to touch the ground.

SMART and COMMIT were sent to Sal island, Cape Verde in September 2006. The statistics of previous year's aerosol optical depth shows that there are some noticeable cycles – prominently 1 week, 3 weeks, and 8 weeks. The one week cycle showed up clearly during the deployment. There are several events when the dust layer descended to the ground, and some properties of dust, such as the single scattering albedo, were captured by COMMIT. The case on September 19 will be shown as an example.



Deployment

The fast response capability of SMART-COMMIT has been demonstrated during the NAMMA experiment when the two mobile labs were flown on a military cargo airplane to Sal island, Cape Verde.



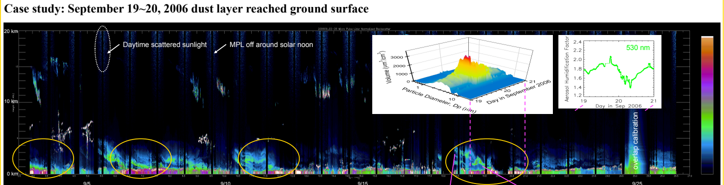
- Shortly after the electricity was connected, the micro-pulse lidar was powered up, and the observation of the Saharan Air Layer began.
- Within a week, all of the three-dozen sensors started to record data.

Instrumentation

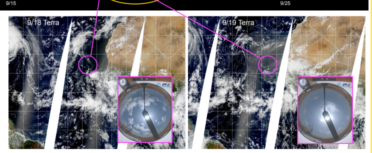
SMART (Surface-sensing Measurement for Atmospheric Radiative Transfer)
Sun Photometers (Cimel, MFR, S^3) - - - - - - - - - direct and diffuse solar radiation at different wavelengths
Broadband Radiometers (PSP, NIP, PIR, …) - - - downward irradiances in different wavelength bands
Spectrometers (ASD, AERI) - - - - - - - - - - - - - - solar and infrared spectrum, ground reflectance
Total Sky Imager (TSI) - - - - - - - - - - - - - - - - - a picture of the entire sky every 10 seconds
Micro Pulse Lidar (MPL) - - - - - - - - - - - - - - - - vertical structure of aerosol and height of cloud layer
Microwave Radiometer (SMiR) - - - - - - - - - - - - precipitable water in the atmosphere, BT from the ground

COMMIT (Chemical, Optical, and Microphysical Measurements of In-situ Troposphere)
Particle Sizer (APS, SMPS) - - - - - - - - - - - - - - - size distribution of aerosol particles
Particulate Monitor (TEOM) -- - - - - - - - - - - - - - mass concentration of aerosol particles
Aerosol sampler (TEOM/ACCU) - - - - - - - - - - - chemical compositions of aerosol particles
TSI Nephelometer - scattering and back scattering coefficients at RGB wavelengths
RR Nephelometers - scattering coefficients at different relative humidity
Aethalometer, PSAP - - - - - - - - - - - - - - - - - - - absorption coefficients at 7 or 3 wavelengths
Gas Monitors - trace gases CO, CO2, O3, SO2, NO and NOx
Meteorological Sensors - - - - - - - - - - - - - - - - - - pressure, air/surface temperature, relative humidity, and wind
Rain Gauges - rain rate and rain accumulation

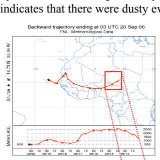
Case study: September 19~20, 2006 dust layer reached ground surface

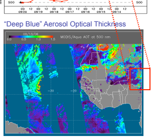


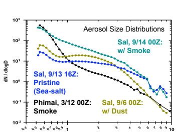
Connected to large scale dynamics, dusty events have been seen periodically on the ground. The sky was relatively clear on 9/18, then it was hazy on the next day. High dust load was observed on 9/20 near the ground surface.



Backward trajectory analysis shows that the dusty air mass came from central Africa a few days ago. Satellite retrieved aerosol optical thickness using the Deep Blue algorithm (Hsu et al. 2006) indicates that there were dusty events associated with the air mass.

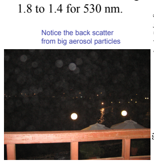


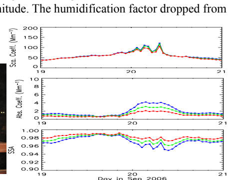


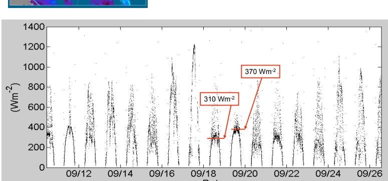


Comparing to pristine or mixed with biomass burning cases, the number size distribution of dusty event in Sal shows a peak between 1 and 2 micron in diameter.

The concentration of super micron aerosol particles increased on 9/20. The scattering coefficient also jumped from below 50 to over 100 Mm^{-1}. The absorption coefficient doubled in red, and quadrupled in blue wavelength. The derived single scattering albedo showed decreased trend of 1% ~ 2% in magnitude. The humidification factor dropped from 1.8 to 1.4 for 530 nm.



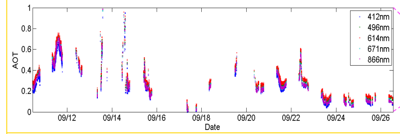


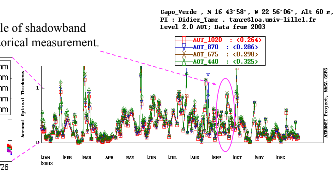


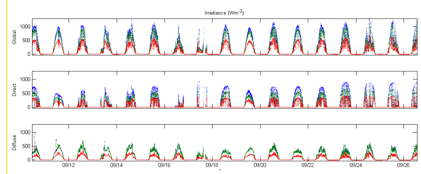
The atmosphere will block some of the incoming solar radiation. The clouds and dust will enhance the effect. As an estimation, about 310 Wm^{-2} was reduced by the atmosphere on 9/18 around noontime, and when the dust layer arrived on 9/19, it increased to 370 Wm^{-2}. Roughly speaking, the aerosol forcing caused by this dust event over the Sal island is about 60 Wm^{-2}. Furthermore, the aerosol optical depth around 500 nm was approximately 0.27 and 0.42 on 9/18 and 9/19 respectively, which leads to a very crudely estimated aerosol forcing efficiency of the dust at noontime: about 400 Wm^{-2}. Because it was always cloudy during the observation period, it is not straight forward to derive the aerosol forcing for the site.

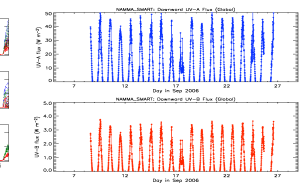
Glance of SMART-COMMIT observations

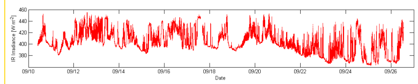
The aerosol optical thickness derived from a couple of shadowband radiometers falls into the same range as in the historical measurement.





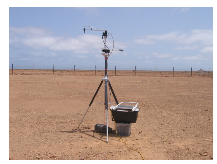


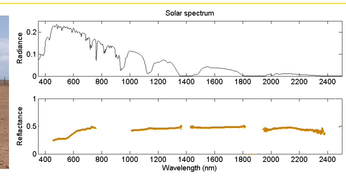


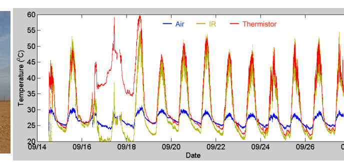


Broadband radiometers measured the irradiance in different wavelength, including 0.3~3, 0.4 ~3, 0.7~3 micron, also in UV and IR band. It became less hazy towards the end of the month, but it remained cloudy.

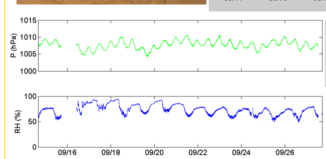
A spectrometer mounted on a tripod was tested for measuring the solar spectrum reflected from a white reference plate and from the ground surface at different viewing angles. The result can be used to crosscheck the satellite retrieved bidirectional reflectance distribution function (BRDF).



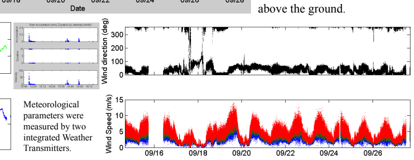




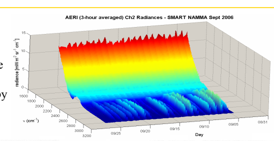
Surface temperature had larger daily cycle than the air temperature. The thermistor touching the ground tracked the IR temperature probe most of the time, except when it rained. The temperature, relative humidity, wind direction and wind speed were measured at 1.3m and 3.5m above the ground.

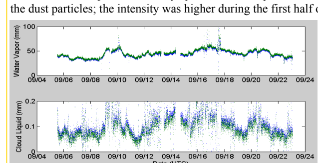


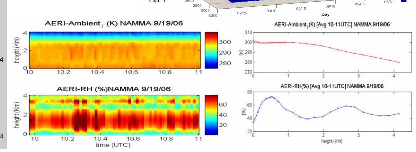
Meteorological parameters were measured by two integrated Weather Transmitters.



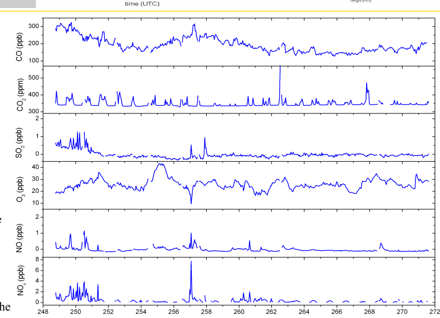
The water vapor in the whole column of the atmosphere was around 50 mm, the cloud liquid water was around 0.1 mm. The vertical profile of air temperature and relative humidity were derived from IR spectrum (Felz et al. 2003), which provides useful information for tracking boundary layer evolution, and may also provide insight into the structure of the Saharan Air Layer and its interactions with dust. The wavelike patterns shown in the 3-D plot reveal daily cycles, which responded to the enhanced scattering by the dust particles; the intensity was higher during the first half of the study.







The measurements from the gas monitors resembled the remote marine environment: CO ~ 150 ppb, SO2 and NOx almost undetectable most of the time, O3 daily maxima ~ 30 ppb, no obvious diurnal cycle in primary pollutants – influences of local emissions are probably small, although peaks in NOx, CO, and SO2 may be attributed to local emissions at times . The first half of the experiment sees some relatively more polluted events.



Summary

The SMART-COMMIT was deployed successfully in Sal, Cape Verde in September 2006. The weekly cycle of dusty event was captured by multiple sensors. Other than remote sensing observations, some optical and physical properties of dust was also measured when the dust layer extended down to the ground surface.

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